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Webbon et al.

[11] **4,095,593**

[45] **Jun. 20, 1978**

[54] **COOLING SYSTEM FOR REMOVING METABOLIC HEAT FROM AN HERMETICALLY SEALED SPACESUIT**

[75] Inventors: **Bruce W. Webbon**, San Jose; **Hubert C. Vykukal**, Los Altos; **Bill A. Williams**, Morgan Hill, all of Calif.

[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**, Washington, D.C.

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[22] Filed: **Dec. 23, 1976**

[51] **Int. Cl.**[2] **A62B 7/14**

[52] **U.S. Cl.** **128/142.7**; 62/259

[58] **Field of Search** ..... 128/142.5, 142.7, 145 R, 128/142.3, 204, 139, 1 A, 1 R, 402, 403, DIG. 27; 2/2.1 R, 2.1 A; 62/259, 298; 165/40; 61/70 R

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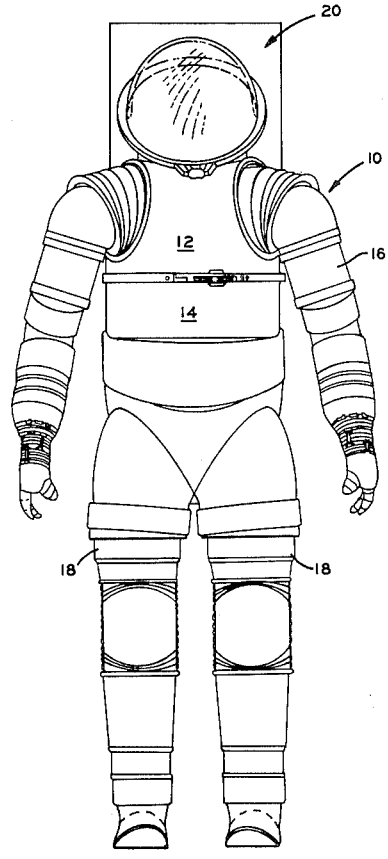
Primary Examiner—Robert W. Michell
Assistant Examiner—Henry J. Recla
Attorney, Agent, or Firm—Darrell G. Brekke; John R. Manning; Armand McMillan

[57] **ABSTRACT**

An improved cooling and ventilating system for removing metabolic heat, waste gases and water vapor generated by a wearer of an hermetically sealed spacesuit. The cooling system is characterized by a body suit having a first circuit for simultaneously establishing a cooling flow of water through the thorax and head sections of the body suit including circulation patches mounted in the thorax section and head section of the body suit, a second circuit for discharging a flow of gas throughout the spacesuit and a disconnect unit for coupling the circuits with a life support system externally related to the spacesuit.

1 Claim, 8 Drawing Figures



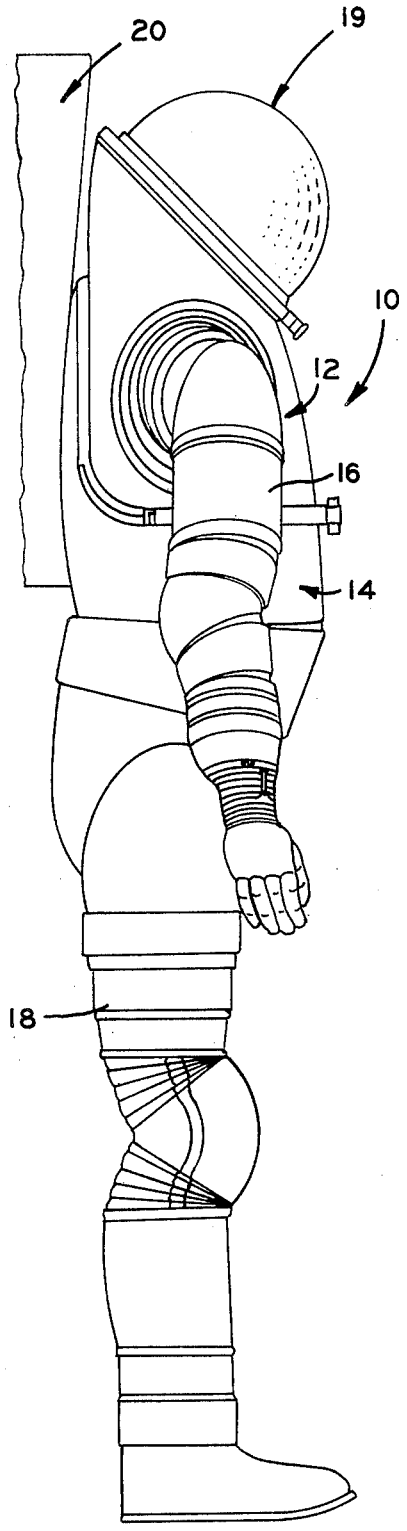


Fig. 1

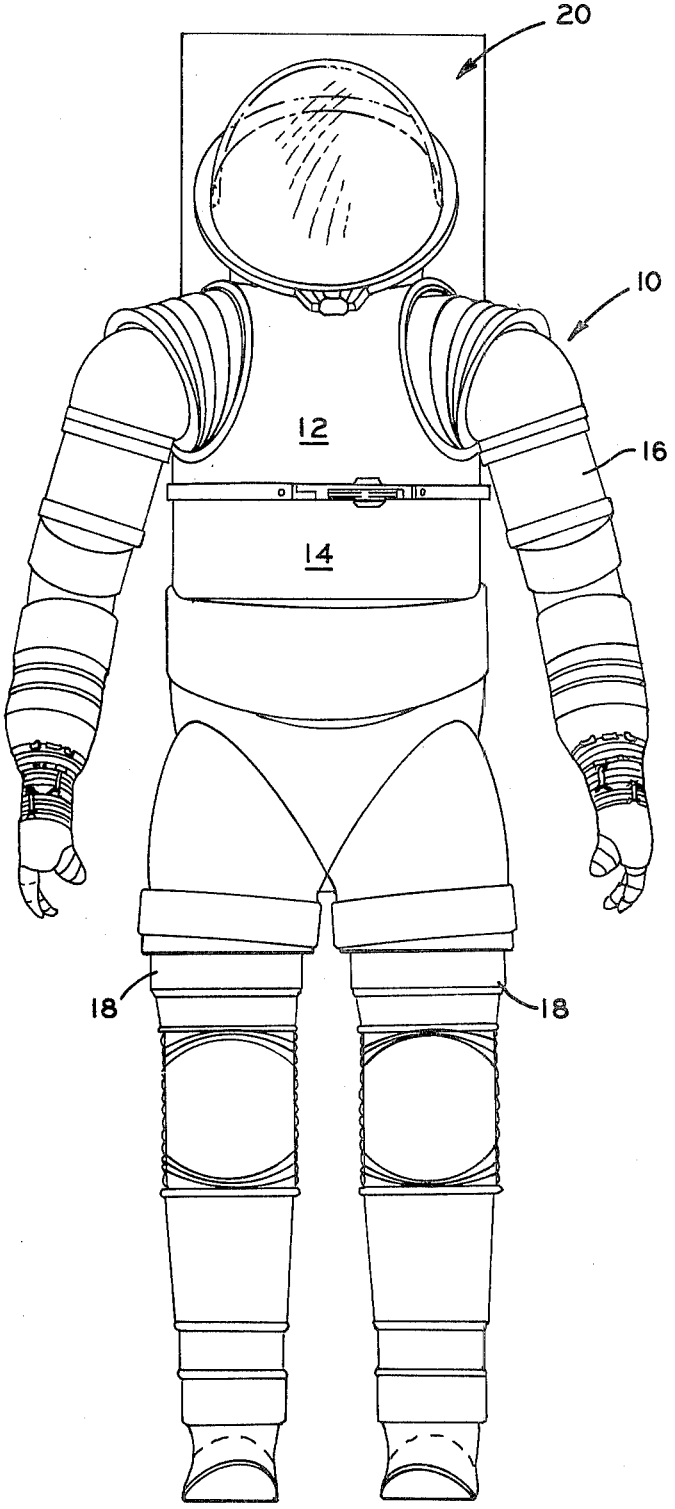


Fig. 2

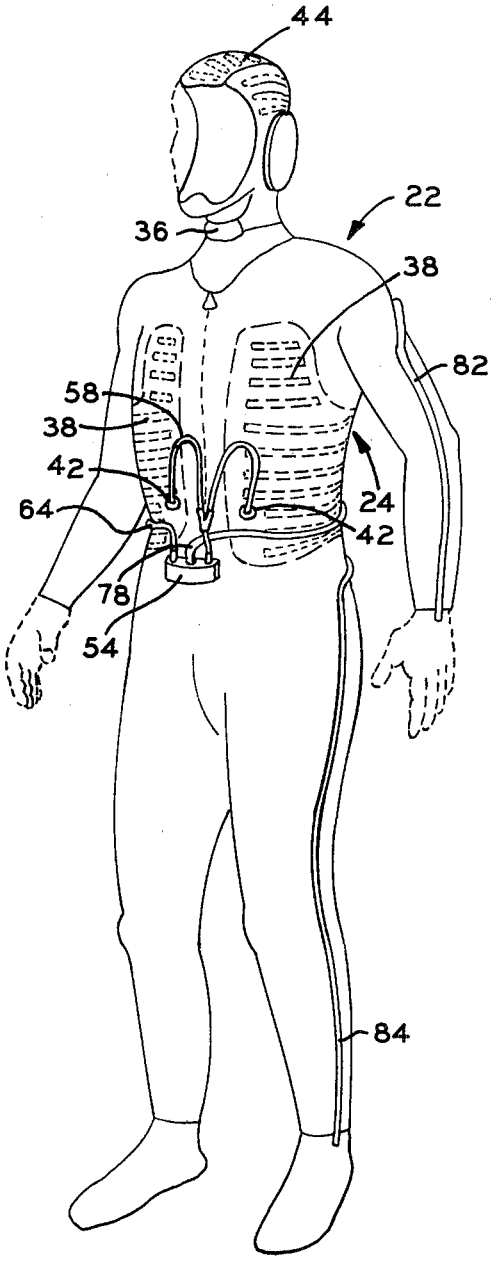

44
22
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Fig. 3

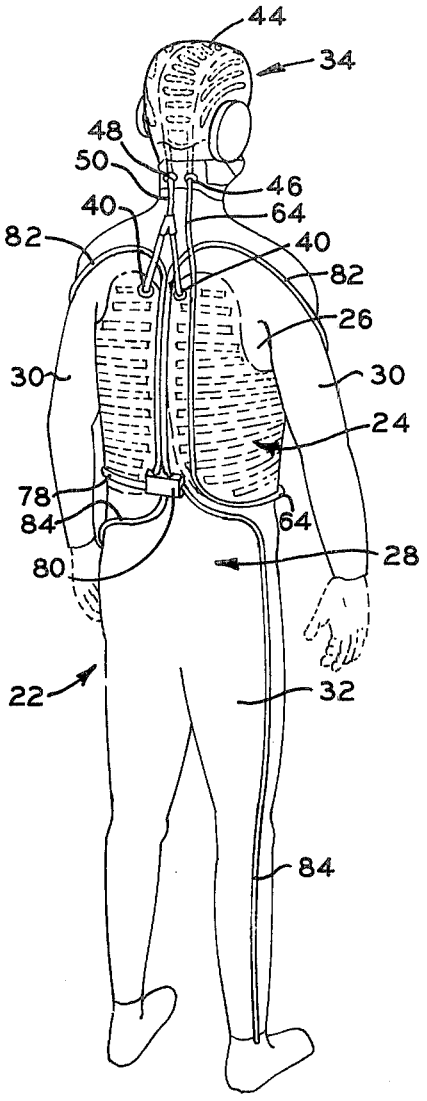
44
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Fig. 4

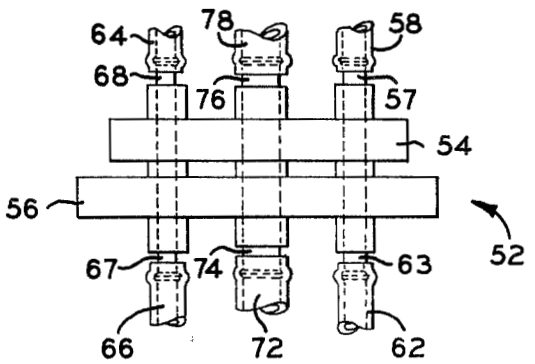

Fig. 6

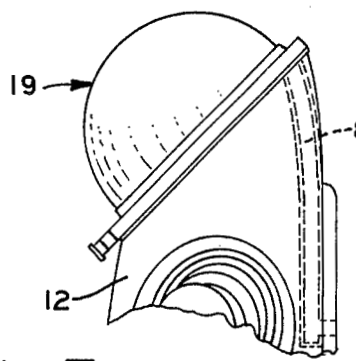

Fig. 7

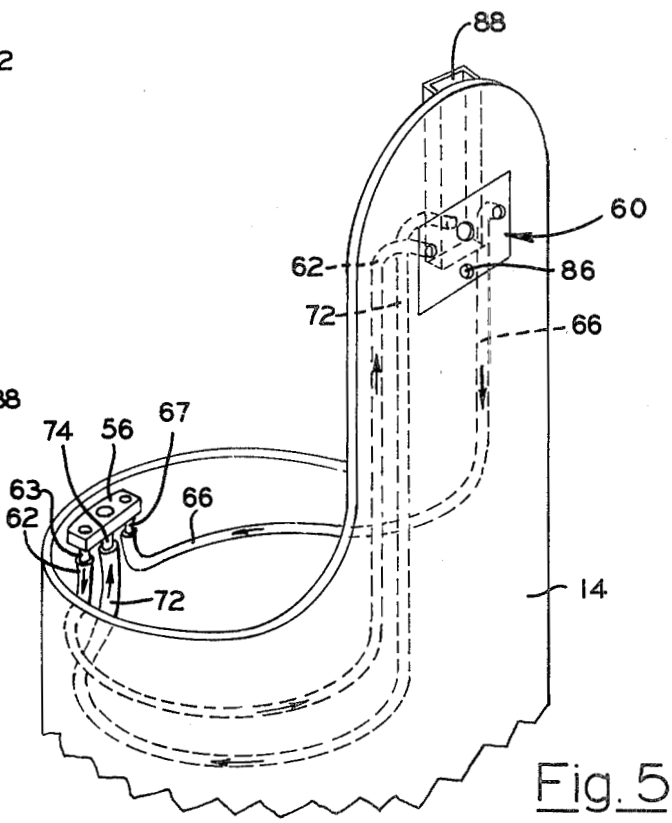

Fig. 5

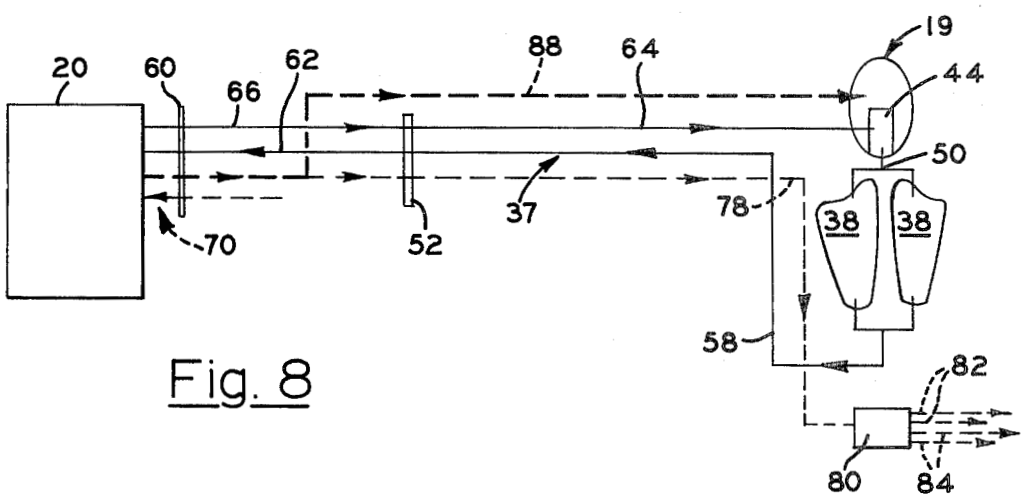

Fig. 8

COOLING SYSTEM FOR REMOVING METABOLIC HEAT FROM AN HERMETICALLY SEALED SPACESUIT

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention generally relates to cooling and ventilating systems for pressure suits and more particularly to an improved cooling and ventilating garment particularly suited for use in removing metabolic heat, waste gases and water vapor from an hermetically sealed outer suit, hereinafter referred to as a spacesuit.

2. Description of the Prior Art

The prior art includes teachings of numerous approaches to the problem of achieving removal of metabolic heat and gaseous wastes generated by a wearer of an hermetically sealed spacesuit. For example, it has been common practice to sew into undergarments for spacesuits cooling circuits including flexible liquid circulating tubes and liquid circulation patches, as well as to employ ventilation systems of numerous configurations for removing waste gases and water vapor from the suit.

In the Apollo/Skylab programs, a cooling unit made of elastomeric material having attached thereto a network of flexible tubes for accommodating circulation of water was employed. The head of the astronaut, hereinafter referred to as a wearer, was not covered and all ventilation gases were fed to the helmet and collected in a return vent system attached to the suit. The cooling system required that a high flow rate of 240 pounds per hour, with temperatures as low as 42° F, be established through the suit in order to remove most of the metabolic heat generated by the wearer. It has been found that the gas circulation systems heretofore employed generally tend to be ineffective in removing perspiration, since the gas becomes substantially saturated with moisture as it exits the helmet of the spacesuit and flows out over the body of the wearer. Moreover, since the entire quantity of gas must be delivered to the suit through small ducts, relatively large pressure drops are experienced when employing such systems. Finally, the tubes heretofore employed in venting spacesuits must be loosely attached to the suit with considerable excess being provided in order to accommodate motion in the region of the joints of the spacesuit. Use of excessive lengths of tubing, of course, tends to increase bulk and is attended by a liklihood that the tubing will experience a collapse, particularly near the mobility joints of the spacesuit.

It is therefore the general purpose of the instant invention to provide in combination with an hermetically sealed spacesuit an improved cooling garment of reduced bulk and complexity, particularly suited for use in removing metabolic heat, waste gases and water vapor from the suit with increased efficiency.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to provide for use in a pressure suit an improved cooling and ventilating system.

It is another object of the invention to provide for use in an hermetically sealed pressure suit characterized by a bulbous helmet affixed to a rigid thorax section of a tubular configuration an improved cooling and ventilating system.

It is another object to provide in combination with an hermetically sealed spacesuit an improved cooling and ventilating system for removing metabolic heat and gaseous wastes generated by a wearer thereof.

It is another object to provide for use in combination with an hermetically sealed spacesuit an improved cooling garment including a network of liquid conduits through which a cooling liquid is circulated about the head and thorax of a wearer, and a circuit for circulating a ventilating flow of gas through the suit, including a network of ducts having discharge orifices located near the head and extremities of the wearer for discharging a flow of gas across the head to the oro-nasal area and along the limbs to the torso region of the wearer.

Another object is to provide an improved cooling and ventilating system particularly suited for use in combination with a spacesuit, although not necessarily restricted in use thereto, since the system may be employed for removing metabolic heat and gaseous wastes from hermetically sealed suits adapted to be utilized in a terrestrial environment.

These, together with other objects and advantages, are achieved through a use of a cooling and ventilating system including an elastomeric body suit adapted to be donned by a wearer of a spacesuit, and having affixed thereto a first circuit network for establishing a cooling flow of water through the body suit and a second circuit network for establishing a flow of gas throughout the spacesuit, as will hereinafter become more readily apparent by reference to the following description and claims in light of the accompanying drawings.

IN THE DRAWINGS

FIG. **1** is a side elevational view of a spacesuit equipped with an improved cooling and ventilating system embodying the principles of the instant invention.

FIG. **2** is a front elevational view of the spacesuit shown in FIG. **1**.

FIG. **3** is a perspective elevational view of a cooling garment comprising a body suit for supporting a cooling and ventilating system which embodies the principles of the instant invention.

FIG. **4** is a rear elevational view of the body suit shown in FIG. **3**.

FIG. **5** is a fragmented perspective view of a lower thorax section of the spacesuit shown in FIGS. **1** and **2**, illustrating plumbing employed in the system of the instant invention.

FIG. **6** is a front elevational view of a quick disconnect unit employed in coupling the body suit shown in FIGS. **2** and **3** with the thorax section shown in FIG. **5**.

FIG. **7** is a fragmented view of a helmet section for the spacesuit shown in FIG. **1**, illustrating a helmet duct through which gas is discharged across the head to the oro-nasal zone of a wearer thereof.

FIG. 8 is a diagrammatic view of a cooling and ventilating system which embodies the principles of the instant invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, with more particularity, wherein like reference characters designate like or corresponding parts throughout the several views, there is depicted in FIG. 1 and FIG. 2 a spacesuit **10** equipped with a cooling system embodying the principles of the instant invention.

As shown in the drawings, the spacesuit **10** includes a thorax section comprising an upper thorax section and a lower thorax section, designated **12** and **14** respectively. Appendages **16** and **18** are provided for receiving the limbs of a wearer. The upper and lower thorax sections preferably are formed of a suitable rigid material and are of a generally tubular configuration. A bulbous helmet **19** is attached to the upper thorax section **12** of the suit **10**, while upon the back of the spacesuit **10**, there is mounted a life support system, generally designated **20**.

It is important to appreciate that the spacesuit **10** and the life support system **20** form no specific part of the instant invention, other than to serve as an outer suit and a source of reconditioned fluids, respectively. Therefore, a detailed description of the spacesuit and the life support system **20** is omitted in the interest of brevity.

Turning now to FIGS. **3** and **4**, therein is illustrated a cooling garment including a body suit, generally designated **22**, which embodies the principles of the instant invention. The body suit **22**, as a practical matter, comprises a support garment of a loosely woven elastomeric material frequently referred to as "loose weave elastic spandex fabric". This material stretches quite easily and thus accommodates substantially unrestricted movement of the wearer. However, it is to be understood that the particular material from which the body suit **22** is fabricated may be varied as desired, so long as the body suit may be donned by a wearer and employed as a support for the system.

As shown in the drawings, the body suit **22** includes an upper torso region, generally designated **24**, which forms a thorax section **26** for the suit **22**, and a lower torso region, designated **28**. Upper limb sections **30** and lower limb sections **32** are provided as an integral part of the body suit **22**. The upper limb sections **30** serve to receive the arms of a wearer with the hands, hereinafter referred to as extremities, exposed. Similarly, the lower limb sections **32** serve to receive the legs of a wearer with the extremities of the legs, or feet, being projected therefrom.

As also shown in the drawings, the body suit **22** further includes a head section **34**. This section is integrally related with the torso region **24** and is of a configuration conforming substantially to a close-fitting, flexible helmet. Straps **36** are provided for securing the head section in place. As a practical matter, the straps **36** are adapted to close over the zone of the throat and/or chin of a wearer and suitable fasteners such as Velcro or the like are utilized for joining the adjacent ends of the straps.

Liquid Circulating Circuit

Incorporated in the body suit **22** there is a liquid circulating circuit **37**, FIG. **8**. The purpose of the circuit is to transport metabolic heat, generated by a wearer, away from the spacesuit **10**.

The circuit **37** includes a pair of circulating patches **38** affixed to the thorax section **26** of the suit **22**. The patches **38**, as a practical matter, comprise liquid circulating patches of the type more fully disclosed in the aforementioned United States Letters Pat. No. 3,830,676. These patches are formed by superimposing flat sheets of flexible material and sealing the sheets together in selected zones for forming chambers having passageways extending therebetween through which the chambers communicate.

Since the patches **38** are of known design and are well understood, a detailed description thereof is omitted in the interest of brevity. It suffices to understand that each of the patches **38** is included in the circuit **37** at an inlet port **40** and an outlet port **42**, and that these ports serve to accommodate ingress and egress of a cooling liquid, such as water or the like, as the liquid is caused to flow through the circuit. The liquid is caused to flow between the inlet and outlet ports **40** and **42**, respectively, for purposes of absorbing and transporting metabolic heat away from the suit, as will hereinafter become more readily apparent.

Similarly, the head section **34** is provided with a liquid circulating patch **44** fabricated in substantially the same manner as are the liquid circulating patches **38**. The circulating patch **44**, however, is configured to cover the top and rear, as well as the temple areas, of a wearer's head and includes an inlet port **46** and an outlet port **48**, disposed in spaced communication.

As a practical matter, the outlet port **48** is connected through a bifurcated length of tubing **50** with the inlet ports **40** of the pair of circulating patches **38**. Thus a cooling liquid introduced into the inlet port **46** of the circulating patch **44** is discharged therefrom through the outlet port **48** to the inlet ports **40** of the circulating patches **38**. It should, therefore, be apparent that a cooling liquid, such as water, introduced into the body suit **22** through the inlet port **46** of the circulating patch **44** will exit the outlet ports **42** of the liquid circulating patches **38** as it is coursed along its return path to the life support system.

In order to accommodate delivery and discharge of a cooling liquid, with respect to the body suit **22**, there is provided a quick disconnect unit, generally designated **52**, FIG. **6**.

The disconnect unit **52**, as shown, includes a body component **54** mounted on the body suit **22**, and a suit component **56** mounted on the lower thorax section **14** of the spacesuit **10**, FIG. **5**. As a practical matter, the disconnect unit **52** is of any suitable design which forms no specific part of the instant invention. However, it is to be understood that the components **54** and **56** are suitably mounted on the body suit and spacesuit, and include suitable male and female couplings, not shown, as well as spring loaded poppet valves. Such valves are well known and serve to afford a "quick disconnect" of the circuit in a manner well understood by those familiar with the design and fabrication of circuits for spacesuits and the like.

As shown in the drawings, each of the outlet ports **42** is connected with the quick disconnect unit **52**, at a discharge nipple **57**, through a bifurcated length of flexible tubing **58**. This length of tubing is extended from each of the outlet ports **42** and is received by the nipple **57**, FIG. **6**. The suit component **56** of the unit **52** is, in turn, connected with a suitable junction plate,

generally designated **60**, provided at the upper rear of the lower thorax section **14** of the spacesuit **10**. The connection is made through a length of flexible tubing **62** attached to the plate **60** as well as to a nipple **63** of the suit component, and coursed about the internal periphery of the thorax section **14** of the spacesuit **10**. The tubing **62** is suitably secured to the spacesuit in order to accommodate movement of a wearer thereof. Hence, it should be understood that water, or other liquid, introduced into the liquid circulating patches at the inlet ports **40** ultimately is delivered to the junction plate **60** for discharge to a circuit, not designated, located within the life support system **20**.

The suit component **56** of the disconnect unit **52** also is connected with the junction plate **60** through a length of flexible tubing **66**. This length of tubing has one end suitably connected with the junction plate **60** while the opposite end thereof is connected with a nipple **67** projected downwardly from the suit component **56**. The flexible tubing **66**, like the flexible tubing **62**, is coursed about the internal periphery of the thorax section **14** and is secured in place for purposes of accommodating movement of a wearer of the suit.

Consequently, it should be apparent that a cooling liquid, such as water or the like, is supplied by the life support system **20** and delivered to the circulating patch **44**, via the lengths of flexible tubing **66** and **64**. The thus delivered cooling liquid then exits the circulating patch **44** and is caused to flow to the liquid circulating patches **38**, via the bifurcated tubing **50**. Ultimately, the cooling liquid is discharged to the life support system **20** via the lengths of tubing **58** and **62** connected in communication by the disconnect unit **52**.

In view of the foregoing, it should be apparent that the disconnect unit **52** serves as a suitable coupling for selectively completing and interrupting the liquid circulating circuit in a manner consistent with that which characterizes disconnect couplings.

Gas Circulating Circuit

Within the spacesuit **10** there is included a gas circulating circuit, generally designated **70**, FIG. **8**. The purpose of this circuit is to deliver dry, consumable gas to the spacesuit **10** and to conduct gaseous wastes therefrom, as perspiration and exhalation occur.

The circuit **70** also is connected with the life support system **20** through the junction plate **60**, aforementioned. To the junction plate **60** there is connected a delivery conduit **72**, formed of a length of flexible tubing, which is extended from the junction plate **60** and connected with the suit component **56** at a downwardly projected nipple **74**, FIG. **6**. The nipple **74** communicates with a nipple **76**, projected upwardly from the body component **54** of the disconnect unit **52**, from which there is extended a length of flexible tubing **78**. This length of tubing is connected with a manifold **80** mounted on the body suit **22** at a suitable location. While the manifold **80** is illustrated as being positioned in the lumber region of a wearer's back, it is to be understood that the manifold may be positioned at any suitable location, such as over the hip zone of a wearer, where desired.

The manifold **80** is of a suitable design having a capability of dividing an incoming stream of gas into four components of substantially equal volumes and pressures. Since such manifolds are well known, and the specific structure of the manifold **80** forms no part of the instant invention, a detailed description thereof is omitted in the interest of brevity.

From the manifold **80** there is extended a first pair of conduits **82** which pass along the outer surfaces of the upper limb sections **30** of the body suit **22**. These conduits also are formed of a flexible material and terminate at discharge orifices, not designated, disposed in close proximity with the extremities of a wearer, as best illustrated in FIG. **3**. Similarly, from the manifold **80** there is extended a second pair of conduits **84** which pass downwardly along the outer surfaces of the lower limb sections **32** and terminate at a discharge orifice, not designated, located above the lower extremities, or feet, of a wearer, as illustrated in FIGS. **3** and **4**.

It should be appreciated that the conduits **82** and **84** are attached in any suitable manner to the body suit **22**. Fasteners, including clips anchored in pads may be employed where desired. Since the particular manner in which the conduits are secured may be varied as desired, and the specific manner in which they are mounted forms no specific part of the instant invention, a more detailed description of the mounting of the conduits **82** and **84** is omitted.

The purpose of the conduits **82** and **84** is to discharge streams of gas near the extremities of a wearer, and thus permit the gas to return upwardly through the appendages **16** and **18** of the suit **10** along the external surfaces of the limb sections of the body suit **22**. These streams ultimately merge within the cavity of the torso of the suit **10** and progress to a gas exhaust duct **86** located in the junction plate **60**. The duct **86** communicates with the interior of the spacesuit **10** and is connected with an exhaust unit, not shown, incorporated in the life support system **20**. As should be apparent, the streams of gas serve to evaporate perspiration formed on the limbs and torso of the wearer, and thus cool the wearer. Of course, the resulting water vapor is transported away from the suit **10**.

In addition to the conduits **82** and **84**, there is provided a helmet duct **88** which serves to flush the helmet **19**, in a continuous fashion, with consumable or life-supporting gas. It is to be understood that the helmet duct **88** also includes an orifice, not shown, positioned near the rear of the head section of the body suit **22** and serves to discharge a continuous stream of gas into the interior of the helmet. This stream sweeps over the head section of the body suit **22** and envelopes the oro-nasal region of the wearer. The gas thus discharged into the helmet **19** ultimately is permitted to pass downwardly into the cavity of the torso of the spacesuit **10** and merge with the gas returning from the appendages **16** and **18**, prior to its being drawn from the suit via the exhaust duct **86**, aforementioned.

It should, therefore, be apparent that the helmet duct **88** serves to direct a flow of dry gas across the head section of the body suit for purposes of supplying oxygen-laden gas to be consumed by inhalation, while simultaneously removing waste gases and water vapor from the helmet **19** as a resulting flushing occurs.

OPERATION

It is believed that in view of the foregoing description, the operation of the device will readily be understood and it will be briefly reviewed at this point.

The body suit **22** initially is donned by a wearer and secured in place utilizing strategically supported fasteners such as zippers and the like, not designated. The liquid circulating patches **38** and **44** are connected,

through lengths of tubing **58** and **50**, respectively, with the body component **54** of the disconnect unit **52**. When arranged in place, the conduits **82** and **84** extend along the outer surfaces of the upper and lower limb sections **30** and **32**, respectively. Once the body suit is properly positioned, the wearer dons the spacesuit **10** and connects the components **54** and **56** of the unit **52** for thus connecting the tubing **58** with the length of tubing **62**, the length of tubing **78** with the tubing forming the conduits **72**, and the length of tubing **64** with the length of tubing **66**. Thus the lengths of tubing **64**, **58**, and **78** are connected to the junction plate **60**.

The life support system **20** is attached to the rear of the spacesuit with a suitable connection being effected between the life support system and the junction plate **60** for thus connecting the circuits **37** and **70** with circuits of the life support system **20**.

A liquid coolant, such as water or other suitable cooling liquid, is introduced into the cooling system via the lengths of tubing **66** and **64**. The liquid now enters the circulating patch **44** of the head section **34** of the body suit **22**. The liquid exits the circulating patch **44** and enters the circulating patches **38**, simultaneously. From the circulating patches **38**, the liquid is permitted to exit the circulating circuit **37**, via the lengths of tubing **58** and **62**. Upon exiting the circuit **37**, the liquid carries with it metabolic heat absorbed from the body of the wearer, particularly within the patches **38** and **44**. The heat thus transported away from the body is dissipated within the life support system **20** in a suitable manner forming no part of the instant invention.

Simultaneously with the circulation of a liquid coolant through the circuit **37**, oxygen-laden gas is introduced into the suit via the conduit **72** and the helmet duct **88**. As the air enters the spacesuit **10**, via the junction plate **60**, a portion thereof is delivered through the tubing **78**, via the disconnect unit **52**, to the manifold **80**. Upon being introduced into the manifold **80**, the gas is divided into four streams and caused to flow through the pairs of conduits **82** and **84** along the outer surfaces of the limb sections of the body suit **22** to be discharged near the extremities of the wearer of the spacesuit **10**. Upon being discharged from the pairs of conduits, the gas moves through the appendages **16** and **18**, toward the torso of the spacesuit, evaporating perspiration and the like. This gas ultimately flows to the gas exhaust duct **86** located in the junction plate **60**. Of course, the gas is there extracted from the spacesuit **10** taking with it undesirable gaseous wastes absorbed and mixed therewith.

Simultaneously, a relatively large quantity of dry gas, a quantity considerably greater than that delivered to the manifold **80**, is directed through the helmet duct **88** and discharged into the helmet **19** at the rear of the head section of the body suit **22** for simultaneously supplying the wearer with consumable life-supporting gases, while sweeping perspiration and waste gases from the helmet **19**. As the water vapor and waste gases are swept from the helmet, they are caused to mingle with the gas returning from the appendages **16** and **18** of the suit **10**, whereupon the merged gases are exhausted at the gas exhaust duct **86** at the junction plate **60**.

In view of the foregoing, it should readily be apparent that the cooling system which embodies the principles of the instant invention provides a practical solution to the problems os supplying suitable quantities of liquid coolants and gas to hermetically sealed spacesuits for simultaneously removing metabolic heat and gaseous wastes.

Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is not to be limited to the illustrative details disclosed.

What is claimed is:

1. In combination with a hermetically sealed spacesuit including a bulbous helmet affixed to a thorax section of a rigid, tubular configuration, an improved cooling system for removing metabolic heat and gaseous wastes generated by a wearer comprising:

an elastomeric body suit including a thorax section, leg sections, arm sections and a head section adapted to be donned by a wearer and received within said spacesuit;

a quick disconnect unit having a first section mounted on said spacesuit interior in reach of said wearer and a second section mounted on said body suit and adapted to be mated in a releasably coupled relationship with said first disconnect section, said first section having first and second inputs and an output mating with first and second outputs and an input, respectively, on said second section;

circuit means for channeling a flow of water through the thorax section and the head section of said body suit, said circuit means coupled between said first outlet and said inlet of said second section of said disconnect unit;

said spacesuit having a water inlet orifice, a water outlet orifice, a gas inlet orifice, and a gas outlet orifice grouped in said thorax section, said orifices being adapted to link to a life support system external to said spacesuit;

means for ducting gas from said gas inlet orifice to the interior of said helmet and to said second inlet of said first section of said disconnect unit;

means for ducting water from said water inlet orifice to said first input of said first section of said disconnect unit and for ducting water from said output of said first section to said water outlet orifice;

a gas distribution network comprising a manifold mounted on said body suit and a flexible conduit connecting said manifold to said second outlet of said second section of said disconnect unit; and

flexible tube means secured to said body suit for channeling gas from said manifold to all arm and leg extremities of the wearer.

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